Lawrence Berkeley National Laboratory
EETD – Applications Team

LBNL Lab Design Guide Test

Case Study Report

September 1999

LBNL Lab Design Guide Test

Case Study Report – September 1999

Executive Summary

A Design Guide for Energy-Efficient Research Laboratories focuses comprehensively on energy issues in highly specialized research laboratory environments. The Guide provides a unique access to literature on pertinent energy design issues and compliments existing in-depth technical manuals. It addresses many antiquated rules of thumb, which often inadvertently cause energy inefficiency. Additionally, the Guide helps designers become aware of debates and issues related to energy efficiency. Perhaps most importantly, the Guide helps with introducing energy decision-making during early in a design process.

This report presents a case study of introducing ideas gained from the Guide during an early phase of a facility's design. The facility will be constructed at the University of California, Santa Cruz (UCSC). The energy-efficiency ideas were introduced during the first value engineering review of the project.

After a Design Program for the UCSC facility was compiled but before Design Development began, the owner's architect reviewed the entire online-version of the Design Guide. From this effort, the architect was able to glean energy-efficient design approaches and ideas presented in the Guide. Once compiled, these approaches and ideas, and in some cases, specific features, were presented and reviewed during the initial phase of value engineering for the UCSC facility.

Comments from the UCSC architect on the application of the Design Guide were obtained during a personal interview in the architect's office. Benefits of using the Guide included:

- Presented a wide scope of ideas from large-scale issue to specifics
- In-depth deign options and alternatives
- Fresh approaches to old design questions
- Increasing the overall knowledge and understanding of the project architect
- Preparing the architect for the upcoming meeting with their mechanical engineer

Some areas of the Guide were found to need improvement including:

- Making the information within the Guide more accessible
- Developing a check list of design approaches and ideas

Testing the Design Guide

Background

The Guide is intended for multiple audiences including building owners, planners, architects, and engineers, and energy utility personnel. It is presented in a hierarchical format. An abstract is presented summarizing each chapter of the Guide, providing a broad overview of the subject. Increasingly specific levels in each chapter are then presented to either satisfy the reader's questions or direct them to further resources.

Manipulation of the large amount of information contained within the Guide has always been a foremost concern. It is understandable that a reader could be easily overwhelmed, and thus frustrated, by the subject of energy efficiency in a laboratory. Although the Guide is presented in a "macro to micro" format and the electronic versions (both web-base and diskette) are fully searchable, a method to lead the reader through the "maze" of information would be beneficial. An anticipated, additional improvement is a method that serves as "road map" both to note location in the energy-efficient design process and to provide a checklist of items both for consideration and that were completed.

Lessons Learned

The UCSC project architect indicated that learned many valuable lessons from using and applying the Design Guide to a Value Engineering process. During an interview with the architect, many ideas were discussed that the guide presented and deserve further consideration including:

1) The Design Guide provided an extensive outline of approaches, ideas, and features for the project's value engineering meeting. The UCSC architect insisted that all topics presented must be addressed.

2) The concept of right sizing is fundamental to getting energy efficiency; include in the design criteria overtly.

3) In general, get energy ideas in during early stages of design process.

4) Be familiar with at least some of the newer technologies

5) Be ready for "engineering as usual" from the mechanical consultant.

6) When pushed, the mechanical engineer relented and said they would review the idea.

7) Modularizing boiler and chiller plants was easy for the mechanical engineer to accept.

8) VAV was a big step for the design approach in the facility.

9) A "diversity factor" is still under discussion.

10) An interstitial space, for routing utility services, was considered but rejected; too costly.

11) Glazing systems figured heavily in the energy efficiency options list.

12) Operable windows are being provided for office areas only (labs were originally included but were immediately rejected).

13) At the time of the interview, no refrigerated air conditioning was being designed for the facility; concerns for conditioning interior spaces exist but the architect is waiting for the Design Development calculations for the final resolution.

14) Night ventilation will figure prominently in the cooling aspect of the facility.

15) Energy efficient lighting evaluations included a large component from natural day lighting in the perimeter office spaces.

16) Wind modeling of the facility will be performed to optimize lab exhaust stack heights and positions.

Design Project Development

Process Overview

In August of 1998, the University of California at Santa Cruz (UCSC) issued a Project Planning Guide (PPG) for a new Physical Sciences Building. The Project Planning Guide included a Statement of Need that examined the overall campus and programmatic needs. The PPG also studied the space needs for natural sciences and engineering. These components constituted 90 percent of the PPG. The description of the desired facility only comprised 10 percent of the document. Therefore, it was not surprising that the PPG did not mention energy efficiency relating to the proposed Physical Sciences Building.

The UCSC project architect recognized the necessity to have energy efficiency measures accounted for in the description of the new building. The architect was made aware of LBNL's *A Design Guide for Energy-Efficient Research Laboratories*. Since the Guide is available entirely on the Internet, the architect created a "wish list" of energy-efficiency ideas by reviewing the Design Guide on-line. Comments from this effort is quite positive and the architect said that he "…learned a great deal…" from his interaction with the Guide. The items included in this wish list are outlined, below, in the "Energy-Efficiency Elements" section.

The next step for the architect was to bring the energy-efficiency ideas to the project's first value engineering meeting. The architect said during our interview that "it was fun…" to have so many items to be included in the session's worksheets that recorded all ideas put forth to be value engineered. The engineering consultant was required to include and address each idea proposed in the first session. The energy-efficiency ideas are presented in the following section under "Work Completed; Value Engineering Ideas".

Energy-Efficiency Elements

As noted above, an outline "wish list" of energy efficiency items and ideas was compiled. It was developed by the UCSC architect during a review of the Lab Design Guide on the web. Each energy efficiency item or idea was enumerated in the following design elements:

Architectural Elements

- Use ceiling fans in the office wing to increase air movement.

- Optimize utility runs by evaluating lab equipment types (standard floor-mounted, end-rigger, c-frame, and unistrut).

- Specify glazing that is appropriate for glazing orientation.

Electrical Elements

- Consider the efficiency and thermal factors of light fixtures.

- Delete incandescent lighting.

Mechanical Elements

- **Right Sizing** - Incorporate "Right Sizing" of mechanical systems and equipment.

- **Boiler Plant** - Use high-efficiency modular boilers to allow staged operation of the plant to match the laboratory's heating load. Consider using isolation valves to prevent circulation during inoperative periods. Carefully calculate laboratory load to provide efficient operation to match loading (to eliminate standby energy needs).

- **Chiller Plant** - Consider chiller efficiencies by accounting for the related pumping costs due to the pressure drop through the chiller. Consider open drive chillers tin lieu of Freon-cooled chillers. Verify if this will reduce energy use because cooling the motors is not required. Consider inexpensively ventilating the chiller room to remove the heat from the motors.

- **Free Cooling** - During cool weather, the outside ambient temperature can help save energy in chilled-water systems. The low temperature of the cooling tower water supply enables free cooling of research laboratories, computer rooms, and office buildings. This free cooling is possible if the central plant incorporates a plate-and-frame heat exchanger to provide chilled water production, which means the chiller's compressor can be shut down. Free cooling can be used to save energy whenever the outside wet-bulb temperature drops below the required chilled water set point. This energy-efficiency measure can save enough compressor electric power to pay for plate-and-frame heat exchanger installation costs in less than two years.

- **Fan Systems** - Consider the most efficient fan "system". Consider lowering system static pressure and improving fan efficiency. Consider the use of centrifugal fans for efficiency (fans add heat to the air stream). Consider the use of direct drive fan/motor combinations as opposed standard V-belt drives and synchronous belt systems. Consider motor efficiency.

- **AHU Pressure Drop** - Examine reducing overall AHU pressure drop. Consider the following items: lowering coil face velocity, filter loading and VFDs, adding bypass dampers (if it can be determined that some AHU components will only be utilized during a portion of the year). Evaluate inlet and outlet configurations of the AHU to avoid inefficient physical restrictions imposed by architectural considerations.

- **Coil placement** - Consider placing fans upstream from the cooling coil and evaporative cooler. In cooling mode, fan heat enhances operation of the cooling coil, and, in heating mode, the same fan heat is used to provide humidification energy and to displace preheat energy input.

- **Sound Power Requirements** - Acoustical attenuators, used to reduce a fan's sound, increase the pressure drop of the AHU. Consider the disadvantages of high-efficiency but noisy fans that will require acoustical attenuation devices. These devices can negate the energy savings from face velocity reductions.

- **Cleanroom Recirculation** - Consider recirculation of cleanroom air systems (reduce both the unidirectional airflow rate and the pressure drop in the air recirculation loop). Review efficiencies of make-up air systems.

- **HEPA Filters** - Consider reduction in the required fan horsepower for cleanrooms by using different airflow velocity through the HEPA filtered air, while the remainder of the cleanroom operates at a lower velocity.

- **Conditioning Alternatives** - Consider displacing conventional cooling and heating energy with natural ventilation. Consider use of evaporative cooling and economizers.

- **Energy Recovery Systems** - Consider extracting heat from the facility's exhaust air stream before it is vented outside. Energy recovery from the laboratory's exhaust should be considered when significant portions of operating hours are at ambient temperature of 50'F (10'C) and below. When properly designed, these energy recovery systems can reduce installed HVAC system capacity by one-half; reduce operating energy from one-third to two-thirds, depending upon mode of operation; and have life-cycle cost paybacks from immediate to three years. The four major energy-recovery systems include run-around coil systems, regenerative heat wheels, heat pipes, and fixed-plate exchangers.

- **Run-around coil systems** - For example, waste heat in the process cooling water from the laboratory equipment can be recovered. Water chiller waste-heat can provide domestic hot water and space heating for laboratories and offices with a run-around coil system.

- **Energy Recovery Location** - Consider energy recovery systems side-by-side exhaust and supply ducting (regenerative heat wheels, heat pipes, fixed-plate exchangers).

- **Lab Equipment Cooling Water** - Consider a small heat exchanger located on every other floor to separate central system cooling water from lab equipment cooling water system. The cooling water discharge from each piece of lab equipment will gravity drain to a holding tank located on every other floor. A small pump will draw cooling water from the tank. The cooling water is then pumped through a heat exchanger and to the supply side of each piece of lab equipment. Appropriate pressure and make-up water controls will be necessary for each piece of lab equipment connected to the cooling water system.

Evaluated Energy-Efficiency Elements

At the time of our interview, three energy-efficiency ideas had been evaluated for implementation.

- Analyze Variable Air Volume (VAV) system, with lower operating cost, versus Constant Air Volume (CAV) system, with less expensive controls, for application in laboratories. CAV had a first cost saving of $243,555 with an annual operating cost increase of $80,600. With about a three-year payback, VAV will be used.

- Review heat gain anticipated from lab equipment; original value of 5 Watts/SF was thought to be low. The load was revised after further study to 7 Watts/SF. Interestingly, the originally designed HVAC system was able to accommodate this 40 percent increase in equipment load. It would seem the first HVAC system sizing did not follow a “right sizing” approach very well.

- Consider ceiling fans in offices for air movement. The cost estimate to install the fans was considered too high. However, it was decided that the expense to provide conduit, wire, and boxes for future fans could be justified at half of the cost for the complete installation.

Work Completed

Interview with Design Guide User

An interview with UCSC project architect occurred on 23 August 1999 at the Facilities Department building on the main Santa Cruz campus of the University of California. The interview was conducted for approximately two and half hours. The featured points of discussion are presented in the Executive Summary, above, and under the Lessons Learned and Energy-Efficiency Elements sections, also above. The results of the recently completed Value Engineering sessions were copied and reviewed. A tally of the review is provided below.

Value Engineering Worksheets

The project design team developed a set of Value Engineering Session Worksheets. The broadest spectrum possible of ideas was included initially to realize the greatest benefit from the value engineering process. Each Worksheet included a main topic relating to each design discipline, a designated team leader, an “idea” to be evaluated, and a resolution/disposition column. The energy-efficiency elements, listed above, were simplified and entered into the idea column of the worksheet as singular statements. In each case, an action code was assigned to each energy element that was either:

- II - Implement Immediately
- FS - Further Study Now
- DD – Study in Design Development
- R - Reject

Value Engineering Ideas

Once presented, each idea was processed by assigning it an action code. The following groups of actions were compiled:

Action Code II (Implemented Immediately)

1) Analyze VAV vs. CAV

2) Isolate piped utilities at each lab

3) Tie into main controls at campus

4) Separate hot water pipe loop for offices with auto control for occupied hours

5) Correct sizing of mechanical equipment

6) Wind tunnel model for all of Science Hill

7) Evaluate configuration of duct to avoid inefficiencies and restrictions

8) Fume hood sash height and face velocity - define

9) Bid alternate to Phoenix system [fume hood VAV system]

10) Full port ball valves at all locations [lower piping system pressure drop]

11) Evaluate engineering wing – pressure vs. labs

12) Domestic and industrial hot water exchanger – delete gas hot water heaters

13) Add bypass dampers at AHU – partial shut down of non-occupied space

14) Use zone pressure sensor at fume hood

15) Evaluate fume hoods – all VAV; all CAV?

16) Evaluate fume hood size and number of walk-ins

17) Capacity of fume hod exhaust system for future expansion

18) Use VFD in lieu of modulating valves

19) Heating hot water pumps on VFDs

20) Use [special] diffusers in high fume hood density labs

21) Review [expected] heat gain from lab equipment

22) Evaluate current and future A/C requirements in labs [right sizing]

23) Conduit paths to roof for future HVAC equipment [optimize utility runs]

24) GreenStar equipment in lieu of obsolete equipment

25) Interior light controls part of VAV controls (sensor turns off VAV)

26) Remote on/off and dimmers at conference and seminar rooms

27) Wiring for ceiling fans in offices

28) Shorter runs between mechanical distribution panels and VFDs

Action Code FS (Further Study Now)

1) **NONE**

Action Code DD (Study in Design Development)

1) Glazing heat mirror vs. low-E
2) Shading of windows consider calculations
3) Energy recovery systems
4) Absorption chiller vs. centrifugal
5) Review shading with landscape – take into account in calculations
6) Delete air conditioning in labs – justify need for A/C per load calculations
7) Multiple control manufacturers/bidders
8) Independent commissioning agent
9) Atrium purge for night pre-cooling
10) Night pre-cooling of engineering block
11) Operable windows vs. pressure [isolation in] labs
12) Size of windows at east, south, and west; overhang; 100% operable
13) Reduce lab air level – what is required? – vary with use
14) Identify all cleanroom requirements [load management]
15) Task lighting at benches
16) Define sash opening height
17) Define hood sizes
18) Define face velocity of hoods
19) Maximize day lighting and minimize heat gain
20) Review location of artificial light vs. daylight
21) Delete incandescent lighting – use fluorescent
22) Use dimmers at floor lights
23) Motor sizes needed for electrical calculations [load management]
24) Lighting controls with building management

Action Code R (Rejected)

1) Chilled water storage

2) Use of Strobic exhaust air fans

3) More passive atrium cooling system

4) Generator – cogeneration combined with chiller system

5) Ice storage system

6) Offices face south and west – relocation due to solar gain [architectural program]

1) Energy recovery from fume hood exhaust to pre-heat air

2) Increase number of fume hood exhaust fans

3) Consider dedicated process chiller

4) Install ceiling fans in offices [only wiring will be installed during construction]

Evaluation of Design Guide Contributions

It is clear that the Lab Design Guide contributed substantially to the project's design process by noting the variety of ideas included in the value engineering worksheets. The UCSC architect used the Design Guide to full advantage in preparation for the project value engineering evaluations. During our interview, it became clear that the Design Guide helped in the following ways by:

- focusing comprehensively on energy issues in highly specialized research laboratory and cleanroom environments.
- providing access to literature on energy efficiency and other pertinent issues that increased the architect's understanding of mechanical systems.
- addressing many antiquated rules of thumb, which often inadvertently cause energy inefficiency.
- increasing awareness of debates and issues that relate to energy efficiency in laboratory facilities.
- complimenting other design references and in-depth technical manuals.

The UCSC architect would have preferred to introduce energy ideas earlier in the design process to influence decision-making during the UCSC Project Planning phase.

Indicated Improvements

Though the Design Guide was helpful, improvements were indicated during the Guide's application. The UCSC architect identified two short-comings in applying the Guide were perceived by LBNL once the Guide became available on the web:

1) Making the information within the Guide more accessible

2) Developing a check list of design approaches and ideas

The Design Guide contains a wealth of information from variety of sources. Accessing and converting this information into knowledge to support a more energy-efficient facility design is yet another effort. The Design Guide does present its information in increasing levels of specificity in each chapter and it is generally organized to present larger, macro design issues at the beginning of the Guide with more micro issues towards the end. However, there is no convenient procedure to build a document that would describe a laboratory's energy-efficient features.

Initially, this document would only have to present a narrative description of energy-efficiency features. Thus, an energy-efficiency narrative includes qualitative, Performance Objectives that describe the project's Design Intent. If known, the Design Intent Narrative can also include Performance Metrics that quantify the energy efficiency of the project. Therefore, a method for accessing information in the Design Guide to help create an Energy-Efficiency Design Intent Narrative is needed.

As a Design Intent Narrative describing energy efficiency is compiled, the designer needs to keep track of where they are in the process. A checklist is method that can structure retrieving information from the Guide. The checklist could be made available as pull-down menu in the electronic and web based versions of the Guide. Another approach is to have the checklist continuously available in a margin next to the text being currently read. The user would then check off topics manually or they could be automatically checked as the topic was accessed.

Principal Results

Link to Design Intent Tool

The Applications Team is building a Design Intent Tool to help organize a facility's design process. This tool --*A Design Intent Documentation Tool*-- provides a unique, structured approach to recording design decisions that influence a facility's energy efficiency. The Tool also provides a method to assist designers and energy managers in identifying and applying advanced energy-efficiency features in laboratory-type environments by linking to *A Design Guide for Energy-Efficient Research Laboratories*. Considerable information is made readily available that pertains to laboratory energy-design issues. The Tool helps its user to:

- introduce energy decision-making into the earliest phases of the design process,
- access energy design information, and
- document design decisions with both qualitative and quantitative criteria.

The primary purpose for developing Design Intent is to state clearly the operational goals that are expected to be met by the facility. This set of goals also forms the criteria for commissioning the facility. A facility's design intent is based on qualitative performance objectives that are developed into quantitative performance metrics for spaces and systems. A Design Intent document is intended to capture and preserve these performance data across the building's life-cycle. Numerous facility and project activities are thus supported by stating the Design Intent including:

- The Participants in project planning are able to document more clearly their desired performance objectives during initial project planning.

- Evaluation of proposed solutions during design are better supported and the resulting decisions are better documented for sharing amongst design team members.

- Assessment of multi-criteria design changes during construction and operations and maintenance (O&M) is improved.

- Commissioning process is more comprehensive and cost-effective supported by access to clearly specified performance targets.

- O&M evaluation of the day-to-day performance of laboratory systems and the early detection and diagnosis of maintenance problems are enhanced through performance benchmarking.

- Performance contracting and measurement and verification are supported in a structured manner.

Developed Checklist

A first effort to develop a Design Guide checklist is presented in the following topic outline. Depending on the stage of design, increased levels of detail and number of items could be provided. At some point, a checklist becomes too long and is no longer useful as a reference or status marker in the design process. However, the checklist should allow for additional items and elements to be added depending on the complexity of the facility's design and the user's depth of experience.

Chapter 1 – Hot Topics

1) Integrated System Design: Right-Sizing for Energy Efficiency
2) Safety & Energy Efficiency Work Together
3) Energy Monitoring and Control System with Direct Digital Control
4) Variable Frequency Drives (VFDs) & Air Flow Rates
5) Modularized Plant Devices
6) Segregating Tasks with Minienvironments
7) Indirect-Direct Evaporative Cooling

Chapter 2 – Architectural Programming

1) Codes Vs. Standards
2) Design Flexibility
3) Laboratory Adjacency
4) Utility Service Spaces

5) Modular Design

6) Minienvironments

Chapter 3: Right Sizing: Choosing an Energy-Efficient Design

1) Life-Cycle Cost Analysis

2) System Sizing

- Optimum mechanical system
- Room air change rates
- Fume hood face velocity
- Cleanroom systems

3) Diversity

- Survey questionnaire
- Diversity factor
- Economics and Safety
- Diversity and VAV systems

4) Load Management

Chapter 4: Direct Digital Control Systems

1) System Sizing

- Optimum mechanical system

2) DDC Implementation

- EMCS Pyramid structure
- Person/Machine Interface

3) Sequence of Operation

4) Total Laboratory Energy Management (TLEM)

Chapter 5: Supply Systems

1) Plant Devices

- Chillers
- Boilers

- Free cooling

2) Air Systems
   - VAV systems
   - Air recirculation
   - Make-up systems

3) Air Handling Units
   - Fans
   - Coils
   - Evaporative cooling
   - Economizers

4) Energy Recovery
   - Run-around systems
   - Desiccant heat wheels

Chapter 6: Exhaust Systems

1) Exhaust Systems and Devices
   - Fume hoods – Type, location, number
   - Fume hood face velocity control
   - Room air challenge
   - Biological safety cabinets
   - Glove boxes

2) Variable Volume Hoods
   - Face velocity control
   - Occupied/Unoccupied Velocity Control

3) Manifolded Exhaust
   - Overview and Advantages
   - Duct static pressure control

4) Effluent Dispersion

- Exit velocity
- Stack heights
- Wind modeling

5) User Interface
   - Training

Chapter 7: Distribution Systems

1) Air Distribution
   - Low-velocity duct design
   - System Effects & Pressure Balancing
   - Leakage and Construction
   - Layout and Fittings
   - Sizing, Simulation, and Optimization
2) Room Pressure Control
   - Laboratory pressure control objectives
   - VAV and laboratory pressure control
   - Sensing and Tracking
   - Enthalpy stabilization
3) Diffusers
   - Discharge velocity and placement
4) Noise Attenuation
   - Fans and Noise
   - Fume hood considerations
   - Active noise attenuation
5) Pumping Systems
   - Variable speed pumping
   - Primary, Secondary, Tertiary Loops
   - Coil pressure Drop

Chapter 8: Filtration Systems

1) Degree of Filtration

2) Filter Pressure Drop

- HEPA filter pressure drop

3) Electronic vs. Media Filtration

Chapter 9: Lighting Systems

1) Lighting Design Considerations

- Task-ambient lighting

2) High-Efficiency Lighting Components

- Lamps
- Electronic ballasts
- Fixtures

3) Lighting Control

- Occupancy sensors and Dimmable ballasts

Chapter 10: Commissioning

1) Installation Verification

- Submittal review
- Construction inspection

2) Operational Assessment

- EMCS and Operational testing
- Operational balancing and calibration

3) Performance Measurement

- Dynamic measurements
- Performance challenge and Fume hood containment verification
- Room pressure control verification

4) Efficiency Assurance

- Baseline energy use

- Verification of EEMs and Estimating energy savings
- Determining monitoring intervals